Call for Proposals:
ROSES11 A.40 COMPUTATIONAL MODELING ALGORITHMS AND CYBERINFRASTRUCTURE
(NOI: 2/3/2012: Proposal Due Date: 3/9/2012) - http://nspires.nasaprs.com/external/

The ROSES11 opportunity in Computational Modeling Algorithms and Cyberinfrastructure (CMAC) solicits proposals that address "new or improved computational modeling algorithms; the exploitation of new computing, storage, and networking architectures; the development of programming and analysis environment, interfaces between observational data and models, large scale observational input data and model output data management, and the adoption of rigorous software engineering standards, practice, and tools." CMAC is also aims to foster development of an interdisciplinary workforce, "especially at the interface between Earth, computing and computational sciences, and software engineering." The solicitation focuses on the information technologies required to enable and facilitate the Modeling and Analysis Program and its supporting information systems. It also seeks proposals to develop an experimental summer education program to supplement the higher education programs at universities.

Specific areas identified in the solicitation are:

- Computational model and analysis algorithms
- Tools and technologies to support management of data
- Tools and technologies to support distributed model development
- Tools and technologies to support model longevity
- Summer Education Program, and
- Technology to Enable Seamless Research Environments.

Research and development in the *Global Modeling and Assimilation Office* (GMAO, http://gmao.gsfc.nasa.gov) at NASA Goddard Space Flight Center is focused on maximizing the impact of satellite observations in the analysis and prediction of climate and weather through integrated Earth system modeling and data assimilation. The goal is to undertake modeling and assimilation as components of an end-to-end process, from defining an instrument, characterizing its in-flight performance, through to the development of algorithms and forward models for data assimilation, integrating the data into assimilation products, and finally assessing the impact of the data on the products of the assimilation system. GMAO is supported by MAP to develop and apply its Goddard Earth Observing System (GEOS) modeling and assimilation systems for NASA science priorities. The current system, GEOS-5, includes both a coupled atmosphere-ocean GCM and data assimilation systems for the atmosphere, ocean and land surface. More information is available at: http://gmao.gsfc.nasa.gov/systems/geos5/ and in the background information below.

In support of Principal Investigators responding to the ROSES11 A.40 solicitation, GMAO will agree to participate as an unfunded collaborator under the following conditions:

1) GMAO is briefed on the scope of the project before the proposal is submitted and the proposal has the potential for improving the capabilities of GMAO's systems,
2) the proposal does not require significant GMAO resources, and
3) the final submitted proposal is made available to the GMAO Chief, Michele Rienecker, Michele.Rienecker@nasa.gov.

In support of the proposed effort, PIs may use the information below about GMAO and how it will support the PI in the stated activity.

Proposals of interest are those that are particular to GEOS-5 to address computational performance of the model, parallel performance of post-processing and diagnostic tools for analysis of model output, transparent access by external users to GEOS-5 products in the NCCS/NAS online and deep data archive that have been identified for open access, an integrated development environment that will support GEOS-5 and its many integrated components, and tools that would contribute to extending the longevity of GEOS codes. GMAO will work with funded activities to:

1) Test the performance of open source parallel Python developments with our model diagnostics package for very high-resolution model configurations.
2) Identify and provide access to a large array of model output files across various storage media at NCCS/NAS for testing new tools/technologies that support management and access to large volumes of data that have mixed access controls.
3) Test new tools for distributed model development that have demonstrated utility with GEOS-5-like modules or that have demonstrated potential for improving the life cycle management of GEOS software.
4) Host a small number of interns as part of a summer education program. These interns must be able to gain unescorted onsite access to the Goddard facility and be approved for access to the NCCS.

This collaborative support will be provided to funded proposals out of existing GMAO resources.

GMAO Background

The Global Modeling and Assimilation Office (GMAO) develops and uses comprehensive models and assimilation systems that support NASA's Earth science research enterprise and contribute to the nation's capabilities in the analysis and prediction of climate and weather. Our role is to maximize the impact of NASA's satellite data in prediction and in analysis and to expand the use of satellite observations in model development and evaluation.

The high quality of today's models and assimilation systems, together with the recognition that improvements in modeling and prediction require attention to the interactions of the different components of the Earth system, have led the drive towards Integrated Earth System Modeling and Analysis (IESM, IESA). GMAO began this integration during the GEOS-5 development by using the Earth System Modeling Framework, by developing ocean and land assimilation capabilities, and by coupling the atmosphere to aerosol and chemistry modules. Our long-term strategy is to continue to develop an IESM and IESA through an incremental, phased approach.

Our modeling strategy is driven by the need to have a comprehensive global model valid for both weather and climate and for use in both simulation and assimilation. The atmospheric component must be a state-of-the-art weather prediction model, and the land and ocean components must accurately represent processes important for modeling sub-seasonal to decadal timescales.
Our primary developments underway in atmospheric modeling are focused towards a global high-resolution non-hydrostatic-capable atmospheric model, with representation of aerosol-cloud microphysical processes. This direction is driven by (i) the need to improve the representation of clouds and precipitation to enable use of cloud- and precipitation-contaminated satellite radiance observations in NWP, and (ii) the research goal of understanding and predicting weather-climate connections.

While we continue to use and improve the GEOS-5 3DVar assimilation system to generate products (e.g., Rienecker et al., 2008), we are also developing a hybrid 4DVar system and contributing to the field of observing system science (e.g. Gelaro and Zhu, 2009; Gelaro et al., 2010), utilizing advanced adjoint-based tools and infrastructure for simulating future observing systems. These directions are driven by the need to (i) account properly for the temporal distribution of satellite observations through the assimilation window, (ii) improve our ability to assimilate cloud- and rain-affected radiances, (iii) contribute to the design of new NASA missions, and (iv) maintain our strong partnership with NOAA/NCEP in advancing assimilation techniques for the nation. We continue to focus on improving the assimilation of NASA satellite data and advancing our capabilities in constituent and aerosol assimilation.

Our current data assimilation is done separately for different components of the Earth system. With our experience in modeling and assimilating the physical, chemical and biogeochemical aspects of the Earth system, as well as generating near-real-time products and forecasts of atmospheric composition, we are taking a phased approach to integrate all of these elements to provide a consistent analysis of Earth's environment, the IESA.

Our strategy for building an IESA is incremental, gradually coupling different components to increase system complexity. Early parts of this phased approach will produce "consistent" simulations and analyses of the various Earth system components. Later phases will include more interactions that capture two-way exchanges between Earth system components. This phased effort builds upon the capabilities developed around the current GEOS-5 system used for near-real-time atmospheric analyses and for our Modern-Era Retrospective analysis for Research and Applications (MERRA). The most recent version of GEOS-5 is coupled with an aerosol assimilation system and with chemistry modules. The ocean data assimilation system implemented in the GEOS-5 AOGCM for ocean reanalyses (e.g., Xue et al., 2012) that are consistent with MERRA and the initialization of short-term climate forecasts provides another increment towards the IESA. Land data assimilation developments are directed towards the assimilation of satellite-derived soil moisture retrievals. The system will be customized for the generation of a SMAP surface and root-zone soil moisture Level-4 product. Assimilation of satellite-derived soil moisture, skin temperature and snow observations are also being integrated with the atmospheric assimilation system. The offline MERRA-Land analysis (Reichle et al., 2011) is another step towards an IESA.

Over the last five years, the distribution of GEOS near-real-time meteorological products has greatly expanded. In addition to the support of NASA instrument teams, we now have a wider and more open distribution, including support of NASA field campaigns and international projects (e.g., such as the WCRP-WWRP Year of Tropical Convection (YOTC)). The product type has also expanded from meteorological analyses to experimental, twice-daily forecasts of weather and atmospheric composition. These forecasts have been provided to guide flight planning for NASA field campaigns, such as ARCTAS, GloPAC, GRIP, and DISCOVER-AQ.

Reanalysis products such as MERRA (e.g., Rienecker et al., 2011) are openly distributed through a partnership with the GES DISC. MERRA fields are also being served on the Earth System Grid (ESG) node at the NCCS to support CMIP5 model evaluation. MERRA and GEOS-5 near-real-time fields are also used to drive regional modeling efforts based on NU-WRF. Other products are targeted for the broader climate science community and as contributions to the U.S. GCRP. These include the contribution of our GEOS-5 seasonal forecasts to the national multi-model ensemble (NMME) being developed under the NOAA/Climate Test Bed activities. A new effort in 2011 has been the generation of decadal forecasts as a contribution to CMIP5 to be used for the next IPCC assessment report. Fields from the GEOS-5 decadal prediction suite are served on the

ESG. An emerging effort is the generation of high-resolution simulations (e.g., Putman and Suarez, 2011) to support the development of new satellite missions – a "Nature Run" – allowing, for example, the simulation of observations for Observing System Simulation Experiments. The huge volume of data from these simulations will be made available to the community but present a challenge from a data-serving perspective.

During the next five years we will continue this approach of developing products from NASA's satellite data streams, supporting NASA instrument teams and the research community. We hope that developments under the A40 ROSES11 solicitation will increase our ability to do this effectively and efficiently.

References:

Gelaro, R., Y. Zhu, 2009. Examination of observation impacts derived from observing system experiments (OSEs) and adjoint models. *Tellus A*, **61**, 197-193. DOI: 10.1111/j.1600-0870.2008.00388.x.

Gelaro, R., R.H. Langland, S. Pellerin, and R. Todling, 2010. The THORPEX observation impact inter-comparison experiment. *Mon. Wea. Rev.*, **138**, 4009-4025. doi: 10.1175/2010MWR3393.1.

Putman, W. M., and M. Suarez, 2011. Cloud-system resolving simulations with the NASA Goddard Earth Observing System global atmospheric model (GEOS-5), *Geophys. Res. Lett.*, **38**, L16809, doi:10.1029/2011GL048438.

Reichle, R.H., R.D. Koster, G.J.M. De Lannoy, B.A. Forman, Q. Liu, S. Mahanama, and A. Toure, 2011. Assessment and enhancement of MERRA land surface hydrology estimates. *J. Climate*, **24**, 6322-6338. doi:10.1175/JCLI-D-10-05033.1.

Rienecker, M.M., and Coauthors, 2008. The GEOS-5 Data Assimilation System - Documentation of Versions 5.0.1, 5.1.0, and 5.2.0. *Technical Report Series on Global Modeling and Data Assimilation*, NASA/TM–2008–104606, Vol. 27. [Available at http://gmao.gsfc.nasa.gov/pubs/docs/Rienecker369.pdf]

Rienecker, M. M., and Coauthors, 2011. MERRA - NASA's Modern-Era Retrospective Analysis for Research and Applications. *J. Climate*, **24**, 3624-3648. doi: 10.1175/JCLI-D-11-00015.1.

Xue, Y., and Coauthors, 2012. A Comparative Analysis of Upper Ocean Heat Content Variability from an Ensemble of Operational Ocean Reanalyses. *J. Climate* (submitted).